Overview of the Accelerated Insertion of Materials – Composites (AIM-C) Producibility Module Development


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Jointly accomplished by BOEING Led Team and the U.S. Government under the guidance of NAST

This program was developed under the guidance of Dr. Steve Wax and Dr. Leo Christodoulou of DARPA. It is under the technical direction of Dr. Ray Meilunas of NAVAIR.
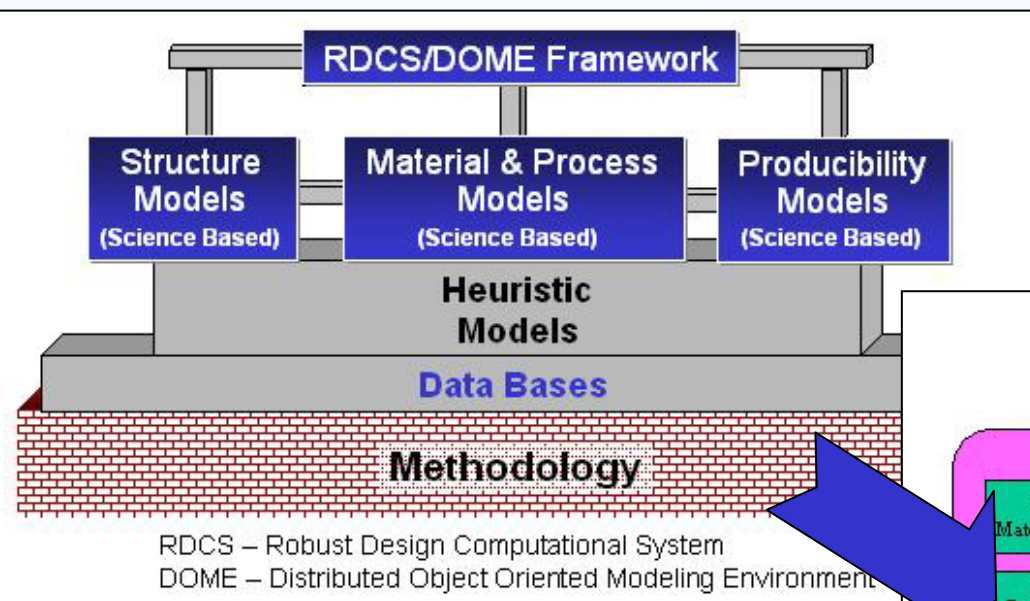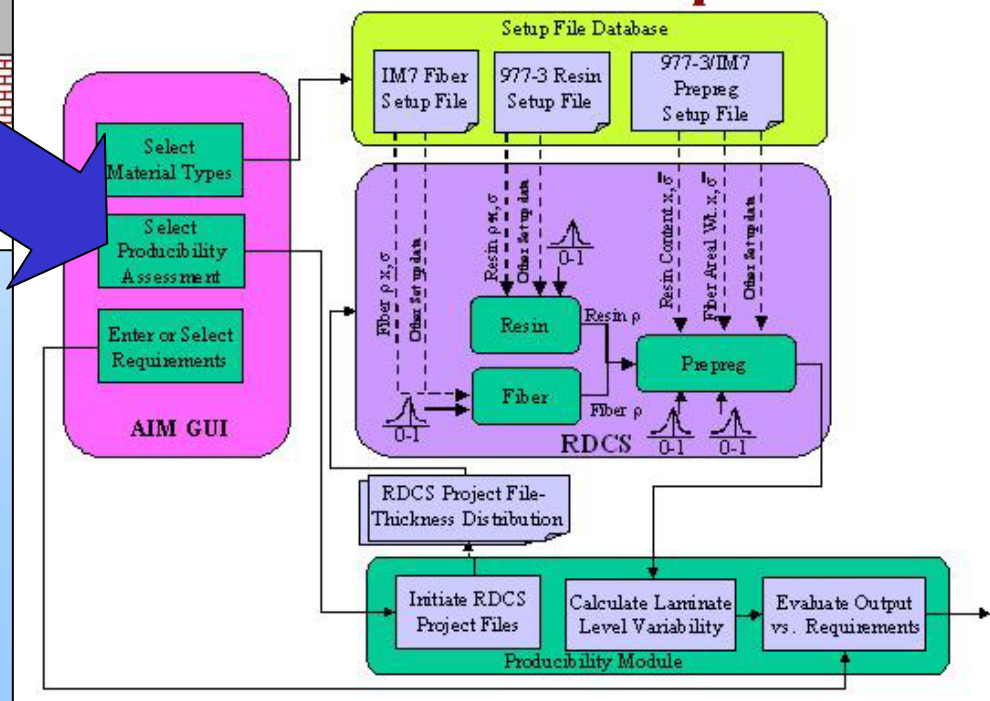
RDCS – Robust Design Computational System
DOME – Distributed Object Oriented Modeling Environment

Most aspects of producibility are very subjective and/or based on previous experience with very little existing software. Therefore, it is being proposed existing software capable of logical programming along with data bases that will contain pertinent information to be interrogated through SQL.

➢ **Heuristic and/or Rule Based Software (Java, Visual Basic, C++….)**

➢ **Knowledge/Data Bases (Access, Oracle, M-Vision,…)**

➢ **Science Based Objective Models (Fortran, C++, etc.)**
- **CACC** (Thickness, Voids/Porosity, Resin Flow Bagging, Debulking, Tooling, etc.)

Red = Basic Activity

Definition:

A Controller Module to Compare Requirements to Manufacturing Capabilities For Quality Components

Corollaries:

- **Can I Make It?**
- **With What Degree of Success?**
- **How Can I Make It?**
- **By Which Manufacturing Sequence Should It Be Made?**

- **The Initial Envisioned Module Provides Heuristics Which Give Guidance Through Part Thermal Processing (Cure/Post Cure)**

- **Does Not Include Hole Drilling or Assembly in Basic Program**

- *For purposes of Bookkeeping in the AIM-C CAT Program, It Also Includes What Hasn't Been Addressed in Other Areas*

AIM-C

Additional Definitions:

➢ **Manufacturing Capabilities**
- Ability to Fabricate the Unassembled Components with Identified Materials and Manufacturing Methods

➢ **Manufacturing/Processing Steps/Areas**
- Ply Cutting
- Layup
- Debulking
- Bagging
- Equipment
- Tooling
- Repairability

➢ **Quality Requirements/ Parameters**
- Meets Functional Requirements (Strength, Stiffness, Dimensions, Etc.)
- Requirements/Parameters are Identifiable, Measurable, and Boundable

➢ **Component Quality Requirements/Parameters**
- Dimensions
- Voids
- Porosity
- Inclusions
- Surface Waviness
- Fiber Volume/Resin Content
- In-Plane & Out of Plane Fiber Distortion
- Surface Finish

➢ **In-Process Quality Requirements/Parameters**
- Ply Angle
- Ply Lap/Gap
- Out Time
- Freezer Time
- Equipment Certifications
- Heat-up Rates
- Cure Time, Temp, Pressure
- Abort Conditions
- Debulk Time, Temp, Pressure

Module Functional Flow Chart

DARPA

NAVAIR

CAD Master Data Tie

Modules/RDCS
- Resin
- Fiber
- Prepreg
- Processing
- Lamina
- Structure
- Durability

Variability/ Error Analysis Results

Knowledge Bases
- Lessons Learned
- Structure Kind, Type..
- Configuration
- Parts
- Secondary Operations
- Repairability
- Sourcing Capabilities/ Capacities
- Equipment
- Tooling
- Quality
- Test Methods

Key Mat'l & Process Controls

Design User Requirements
- Kind of Structure (Skins, Substructure, Doors, Etc.)
- Class of Structure (Primary, Secondary, etc.)
- Type of Structure
- (Monolithic, Cocure, Etc.)
- Configuration/Features
- Tolerances
- Fiber/Fiber Form
- Fiber Volume/ Resin Content
- Quality (Voids, etc.)
- Additional Matl's
- Secondary Operations
- Repairability
- Manufacturing Methods

Producibility Module

CACC

Methodology (Divergence/Risk)

CAICAT, ATMCS, FiberSim, Panform

Other User Requirements

Certification User Requal Requirements
- Changed Mat'l, Process, Equipment, Tooling

Outputs
- Divergence/Risk for Requirements Relative to Capabilities
- Risk Reduction Recommendations
- Costs/Times
- Design/Manufacturing Recommendations
- Mat'l & Process Spec Recommendations
- Quality Plan/Recommendations
- Indirect Materials
- Tooling Definitions/Concepts

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Knowledge/Data Bases

Manufacturing/Processing Steps
- Cutting
- Layup
- Debulking
- Cure
- NDE/Quality
- Testing

Equipment
- Cutting
- Collation
- Ovens
- Autoclaves
- NDE
- Testing

Lessons Learned
- Configuration/Type/ Class (Parts)
- Methodology
- Material(s) and Material Combinations
- Manufacturing/ Processing Steps
- Tooling
- Equipment
- Quality (In-process and Final Part)
- Testing/Evaluations
- Secondary Operations
- Repair
- RDT&E Costs/Times?

Tooling
- Primary Tooling
- Secondary Tooling

Secondary Operations
- Bonding
- Painting
- Coating

Repair
- In-process
- Final Part (After Cure)
- Material Compatibility

Other
- Health & Safety
- ITAR
- Proprietary Info

Cause and Effect Diagrams
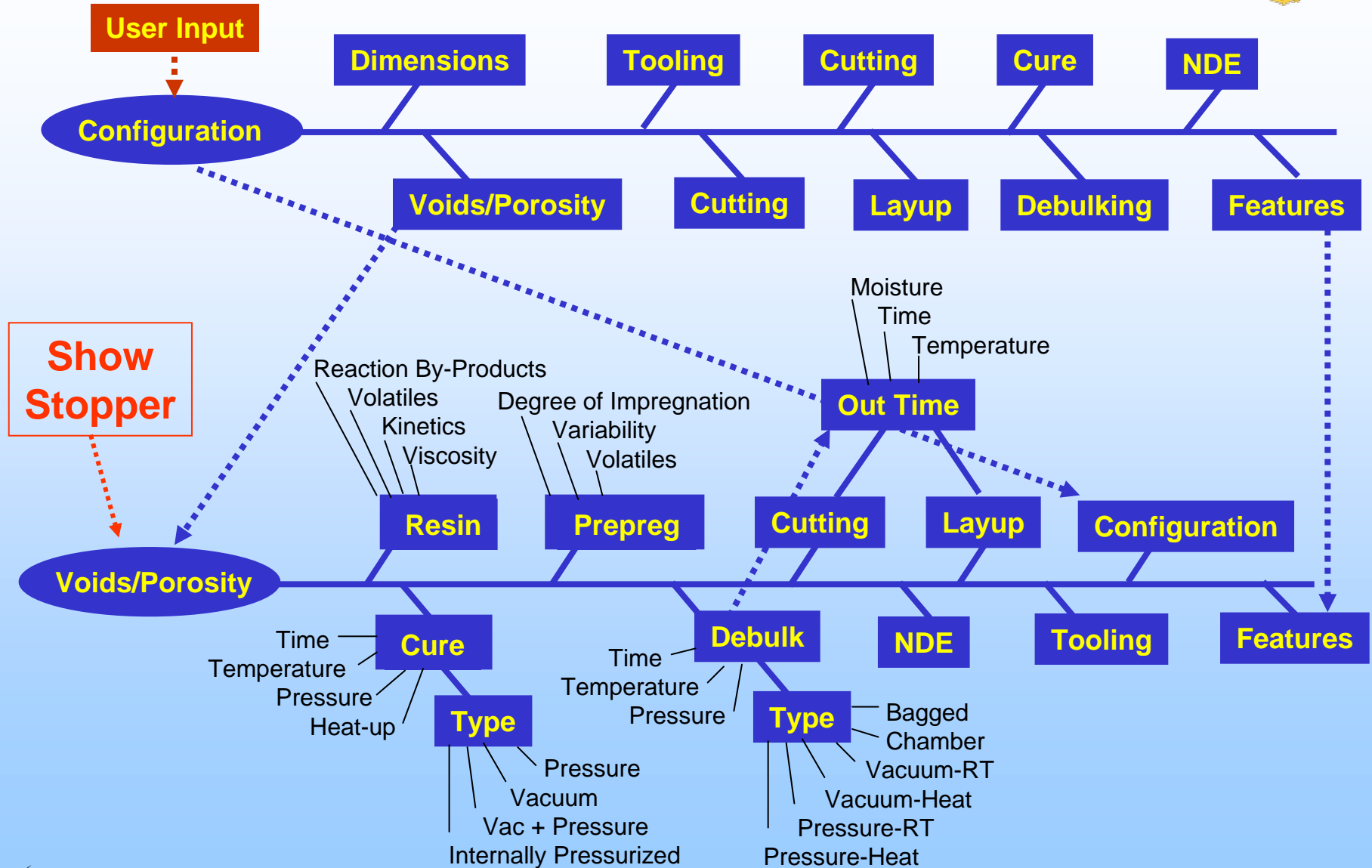
AIM-C

AIM-C Producibility Module

Producibility Module Has Integrated Components That In Turn…….

Other AIM-C Modules

Producibility Analysis & Decision Support Model

Producibility Integration Layer

Designer's Module

Producibility Evaluation User's Module

Collaboration & Communication Model

Database Management Model

AIM-C System Communication & Integration Functions

Components
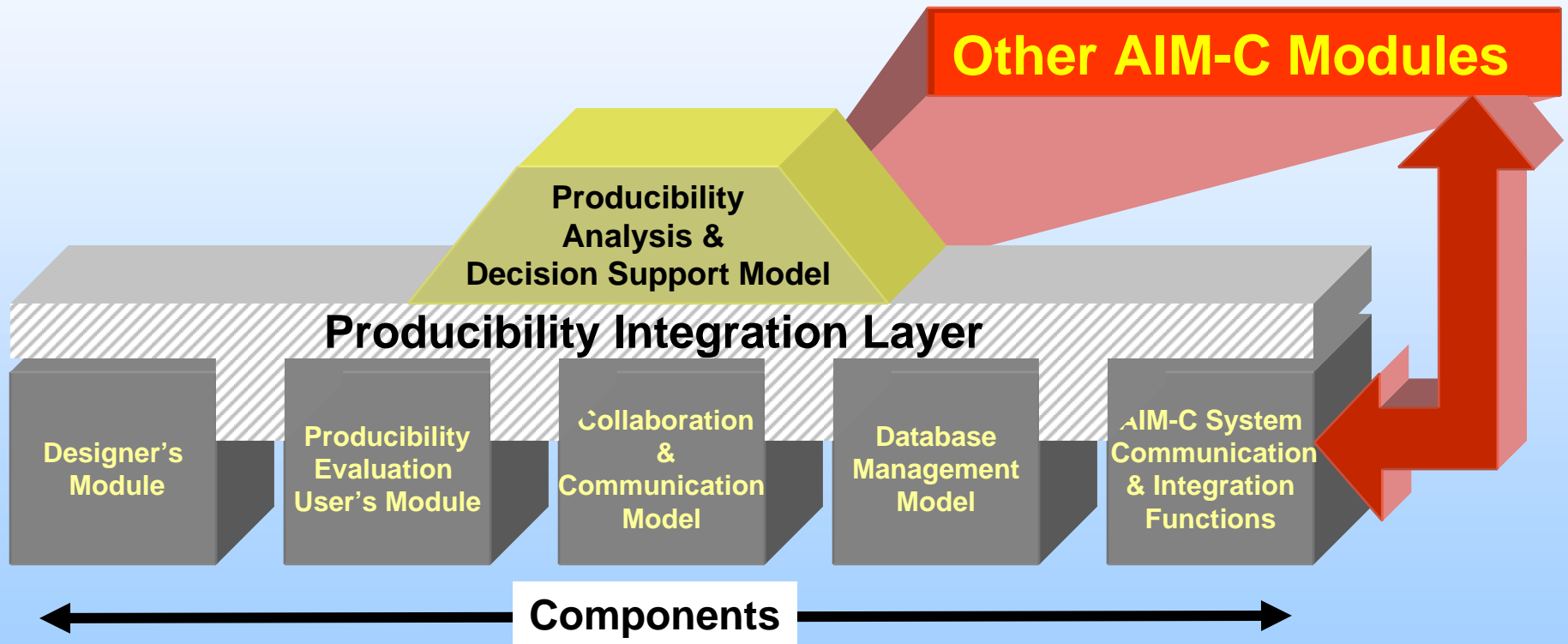
…..Are Integrated With Other AIM-C Modules

Producibility Module Demo Overview

Design User Inputs

Knowledge/Data Bases

Lessons Learned

Producibility Item(s) Evaluation

Referenced/ Required Information

Indirect Materials

Testing/ Specs

• Thickness
• Voids/Porosity
• Cutting
• Indirect Matl's

Producibility Evaluation Outputs
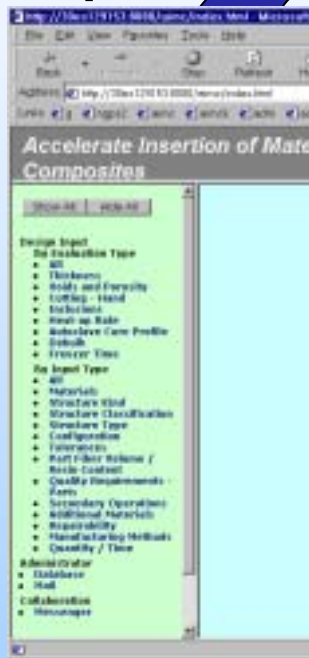
• Primary Matl's
• Size/Thickness
• Features
• Tolerances
• Quality Requirements
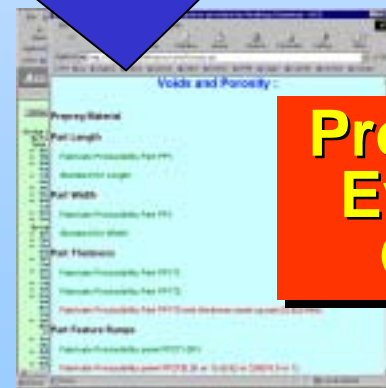
Starting Module Design User

- **Control of Users**

- **Multiple User Types**

- **Administration Control for Data Bases**

- **Design User Variables for Producibility**

- **Producibility Evaluations From a Design User Standpoint**

- **Producibility Evaluations From a Producibility User Standpoint**

Design User Inputs

Design User Definable Variables

- **Design User Sets Problem/Require-ments For Producibility Evaluations**

- **Ties to Other Design User Items**

- **Allows Individual Producibility Item Evaluations or All Items**

Producibility Evaluations/Outputs According to User Inputs/Requirements

Producibility – Quality Thickness

Ties to Resin, Fiber, and Prepreg Modules

AIM-C
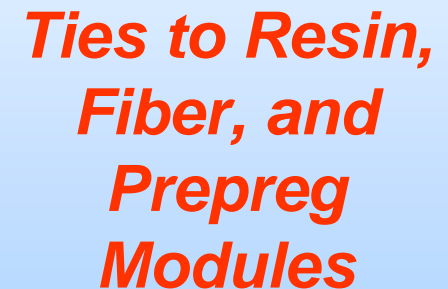
Producibility – Quality: Thickness

Thickness for Producibility Evaluation

	Avg	Min	Max
Number of Plies	N/A	25	76
Per Ply Thickness	0	0	0
Min Part Thickness	0	0	0
Max Part Thickness	0	0	0

Problem: min part thickness is 0

Problem: max part thickness is 0

View Test Method

Testing

Multiple Output Options and Information

Specifications

Identification of Potential Problems

Producibility – Quality: Voids

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Producibility – Quality: Voids

Voids and Porosity :

Prepreg Material

Part Length

Fabricate Producibility Part PP1 (view).

Standard for Length

Part Width

Fabricate Producibility Part PP1 (view).

Standard for Wi... **Part Thickness**

Part Thickness

Fabricate Producibility Part PP1T1 (view) and Thin test panel [0.0] inches thick.

Fabricate Produ... Fabricate Producibility Part PP1T2 (view).

Fabricate Produ... Fabricate Producibility Part PP1T3 (view) and thickness scale-up part [0.0] thick.

Fabricate Produ... **Part Feature Ramps**

Part Feature Ra... Fabricate Producibility panel PP2T1-2R1 (view).

Fabricate Produ... Fabricate Producibility panel PP2T[0.0 or 1]-[0.0 or 2]R[0.0 or 1] (view).

Fabricate Produ... **Part Quantity - Voids**

NDE Standards (Effect of Defect)

Fabricate NDE standard part PP_NDE2 (view) with [0.0 %] voids.

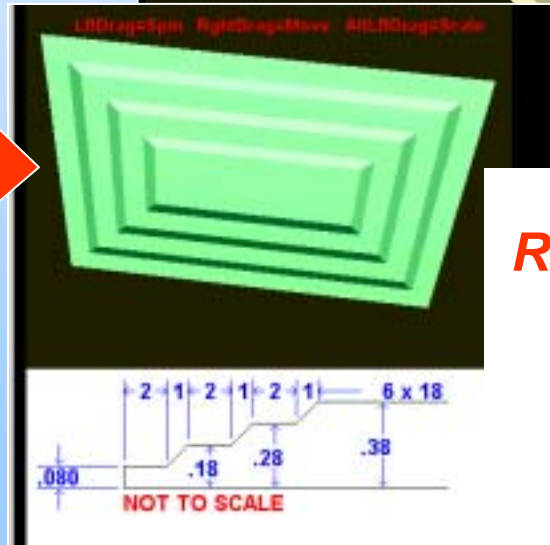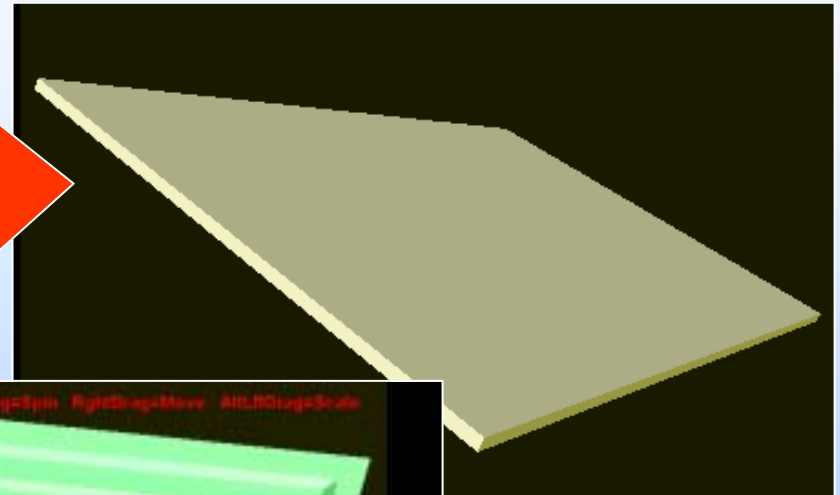Fabricate NDE standard part PP_NDE2 (view) with 2X[0.0 %] voids.

Fabricate NDE standard part PP_NDE2 (view) with 3X[0.0 %] voids.

Mechanical Property Panels (Effect of Defect)

Fabricate Compression test Panel[s] CTP1 (view) with [0.0 %] voids.

Fabricate Compression test Panel[s] CTP1 (view) with 2X[0.0 %] voids.

Fabricate Compression test Panel[s] CTP1 (view) with 3X[0.0 %] voids.

LBDrag=Spin RgktDrag=Move AltLBDrag=Scale

2 -1- 2 -1- 2 -1   6 x 18

.18   .28   .38

.080

NOT TO SCALE

Output Recommendations Based on User Inputs, Std Produce Tests, and Lessons Learned

Producibility – Method: Cutting

Cutting - Hand

Please specify Product Name and click Calculate :

[Calculate] [Open] [Save]

Resin:	Type:	977-3					
Fiber:	Type:	3K	Form:	5HS	Kind:	AS4	
Backing Paper:	Product Name:	Product A					
Separator Material:	Product Name:	Product A					
Spool Requirements:	Facility:	Boeing	Weight(lbs):	10	Diameter(inches):	5	Width (inches): 100
Resin Environment Requirements:	Storage greater than 5'						
Part Quality:	Inclusions:	Cutting					
In-process Quality:	Angle Accuracy:		Facility:	Boeing	Cutting Angle Accuracy:	overall average	

Methods Take Into Account Facilities/Capabilities, Direct Materials, Indirect Materials, Part Quality, In-Process Quality, and Interactions With Other Items

Producibility User Design Input
- All
- Materials
- Structure Kind
- Structure Classification
- Structure Type
- Configuration
- Tolerances
- Part Fiber Volume / Resin Content
- Quality Requirements - Parts
- Secondary Operations
- Additional Materials
- Repairability
- Manufacturing Methods
- Quantity / Time

Producibility User Variables
- All
- Thickness
- Voids and Porosity
- Cutting - Hand
- Inclusions
- Heat-up Rate
- Autoclave Cure Profile
- Debulk
- Freezer Time

Administrator
Collaboration

AIM-C

Producibility – Method: Cutting

Results for Cutting - Hand

Prepreg Material - Indirect Materials

Backing Paper

Product A associated with Prepreg

Evaluate prepreg backing paper per??? Specification for NDE detectability and contamination.

Product A associated with NDE Compatibility

Evaluate prepreg backing paper per??? Specification for contamination.

Separator Material

Evaluate prepreg separator per??? Specification for prepreg usage.

Product A associated with ResinID 1

Product A associated with NDE Compatibility

Evaluate prepreg separator per??? Specification for prepreg usage, NDE detectability, and contamination.

Prepreg Material - Spool Requirements

Cutting Capability

There is a conflict between cutting capabilities and prepreg spool ???, Needs Investigation.

Resin Environment Requirements

Prepreg Material - Spool Requirements

Cutting Capability

There is a conflict between cutting capabilities and prepreg spool ???, Needs Investigation.

Resin Environment Requirements

TBD.

Part Quality - Inclusion

Indirect Materials - Cutting

Product A associated with Cutting

Evaluate cutting separator per??? Specification for prepreg usage.

Product A associated with NDE Compatibility

Evaluate cutting separator per??? Specification for prepreg usage, NDE detectability, and contamination.

In-process Quality - Angle Accuracy

Angle accuracy capability (total layup angle accuracy/repeatability) can not meet quality requirments of [angle accuracy] because cutting accuracy/repeatability is ?? And layup accuracy/repeatability is ??.

Secondary Operations

tgest per ??? Specification

Part Dimensions

Producibility User Producibility – Quality: Thickness

Producibility User Producibility – Quality: Thickness

Administrator User
Data Base Management

AIM-C

Collaboration User Messenger

AIM-C

Summary

- ***Demonstrated:***
  - Design User Interface for Producibility
  - Producibility Quality Areas of Thickness and Voids
  - Producibility Operation/Processing Area of Cutting and Indirect Materials
  - Recommendations Based on Inputs and Lessons Learned
  - Integration of Producibility Module Multiple Component Pieces
- ***Approach Is Viable As Module Has Evolved***